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Air and vegetation monitoring in the vicinity of a phosphorus plant: 1981-1983 results

S.S. Sidhu

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AIR AND VEGETATION MONITORING IN THE VICINITY OF A PHOSPHORUS PLANT: 1981-1983 RESULTS

by S.S. Sidhu

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ABSTRACT

Results of a 3-year (1981 to 1983) air and vegetation monitoring program for fluorides in the vicinity of a phosphorus plant, Long Harbour, Newfoundland are presented in this report. Seasonal and annual flux of gaseous fluorides in the air were monitored weekly by a static method using Na-formate filter papers. The F- accumulations in air were correlated with the F- accumulations in foliage of balsam fir and alder. The results are assessed in terms of the Provincial Air Pollution Control Regulations.

Since 1980, the weekly F-deposition on fluoridation plates varied widely, e.g. 29.62 to 422.79 µg $F/dm^2/7$ days in 1983. There was an increase in the F- concentrations in air from 1980 to 1981 and 1982. However, there was a drop of 13 to 70% in 1983, mostly due to lower F- levels during August 1983. The F- accumulation in balsam fir and alde. foliage correlated well with the F- levels in air. During the monitoring periods in 1981 to 1983, provincial fluoride vegetation and air standards were probably not met up to a NE-distance of 5.8 to 8.0 km from the source.

RÉSUMÉ

Sont présentés les résultats d'un programme de contrôle des concentrations de fluorures dans l'air et la végétation, qui a été réalisé pendant trois ans (de 1981 à 1983) près d'une usine de phosphore à Long Harbour (Terre-Neuve). Le flux de fluorures gazeux dans l'air a été mesuré chaque semaine par une méthode statique à l'aide de papiers-filtres imprégnés au formiate de sodium. Les accumulations de F- dans l'air étaient en corrélation avec les accumulations dans le feuillage du sapin baumier et de l'aulne. Les résultats sont examinés dans le contexte de la réglementation provinciale sur la lutte contre la pollution atmosphérique.

Depuis 1980, les dépôts de F- mesurés pour sept jours varient considérablement; par exemple, ils ont fluctué entre 29,62 et 422,79 $\mu g/dm^2$ en 1983. Il y a eu augmentation des concentrations de F- dans l'air de 1980 à 1981 et 1982. Par contre, en 1983, on a observé une baisse de 13 à 70%, en majeure partie attribuable aux concentrations plus faibles enregistrées en août. On a constaté une bonne corrélation entre l'accumulation de F- dans le feuillage du sapin baumier et de l'aulne et la concentration dans l'air. Durant les périodes de mesure de 1981 à 1983, les normes provinciales relatives au fluorures dans la végétation et l'air ont probablement été dépassées au nord-est de la source jusqu'à une distance de 5,8 à 8,0 km.

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AIR VEGETATION MONITORING IN THE VICINITY OF A PHOSPHORUS PLANT: 1981-1983 RESULTS

by

S.S. SIDHU

1. INTRODUCTION

Since the spring of 1976, the Newfoundland Forest Research Centre (Canadian Forestry Service) has operated a network of air and vegetation monitoring stations to evaluate the seasonal and annual flux of fluoride in air and vegetation in the vicinity of a phosphorus plant located at Long Harbour (47°26'N, 53°47'W), Newfoundland (Fig. 1).

The results of monitoring for the period 1976 to 1980 were reported by Sidhu (1981). This report documents the results for 1981 to 1983.

2. MATERIAL AND METHODS

2.1 Study Area and Location of Monitoring Stations

Earlier air and vegetation monitoring studies at Long Harbour established that most fluoride damage to vegetation occurred within 13 km in a NE-direction from the emission source (Sidhu and Roberts 1975 and 1976; Sidhu 1980). As a result of these earlier studies six permanent monitoring stations were established along a SW-NE transect up to a distance of 18.7 km from the source. During 1981 to 1983 fluoride in the air was monitored weekly at least from 1 June to 31 August of

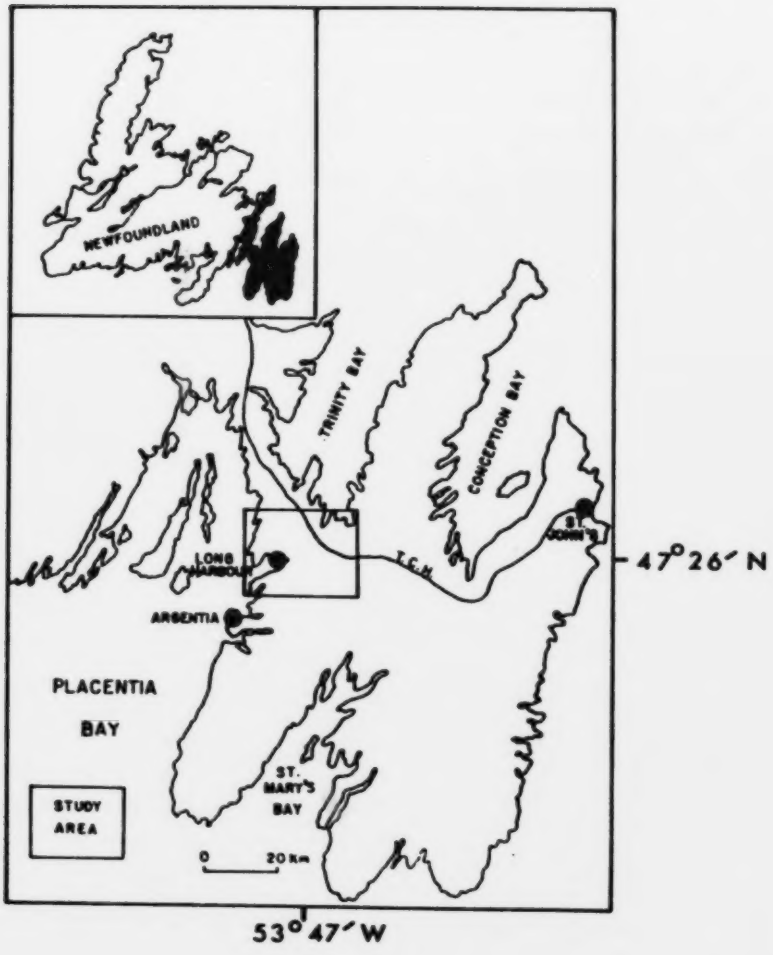

Fig. 1. Map showing the location of the study area.

each year. This duration covered a period of active growth of most plant species in the Long Harbour area. The locations of the monitoring stations are presented in Table 1 and Fig. 2.

Table 1. Locations of permanent air and vegetation monitoring stations in the Long Harbour area from 1981 to 1983.

Station No.	Map - Grid Reference*	Direction from Source	Distance (km) from source
A_2	884 564	ENE 71°	1.4
A_{12} (truck depot)	914 582	ENE 59°	4.6
A_4	924 587	ENE 59°	5.8
A_5	940 605	NE 54°	8.0
A_6	955 624	NE 50°	10.3
A_9	991 707	NE 36°	18.7
A_{14}	924 492	SE 142°	8.5

* NTS grid reference for 1:50,000 scale maps.

2.2 Method of Air Monitoring

The levels of gaseous fluorides in the air were monitored by a modified static method previously described and used by Carlson et al. (1974). Circular filter papers (Whatman No. 40, 63.62 cm^2) enriched with 10% Na-formate were stuck inside plastic petri dishes with acetone.

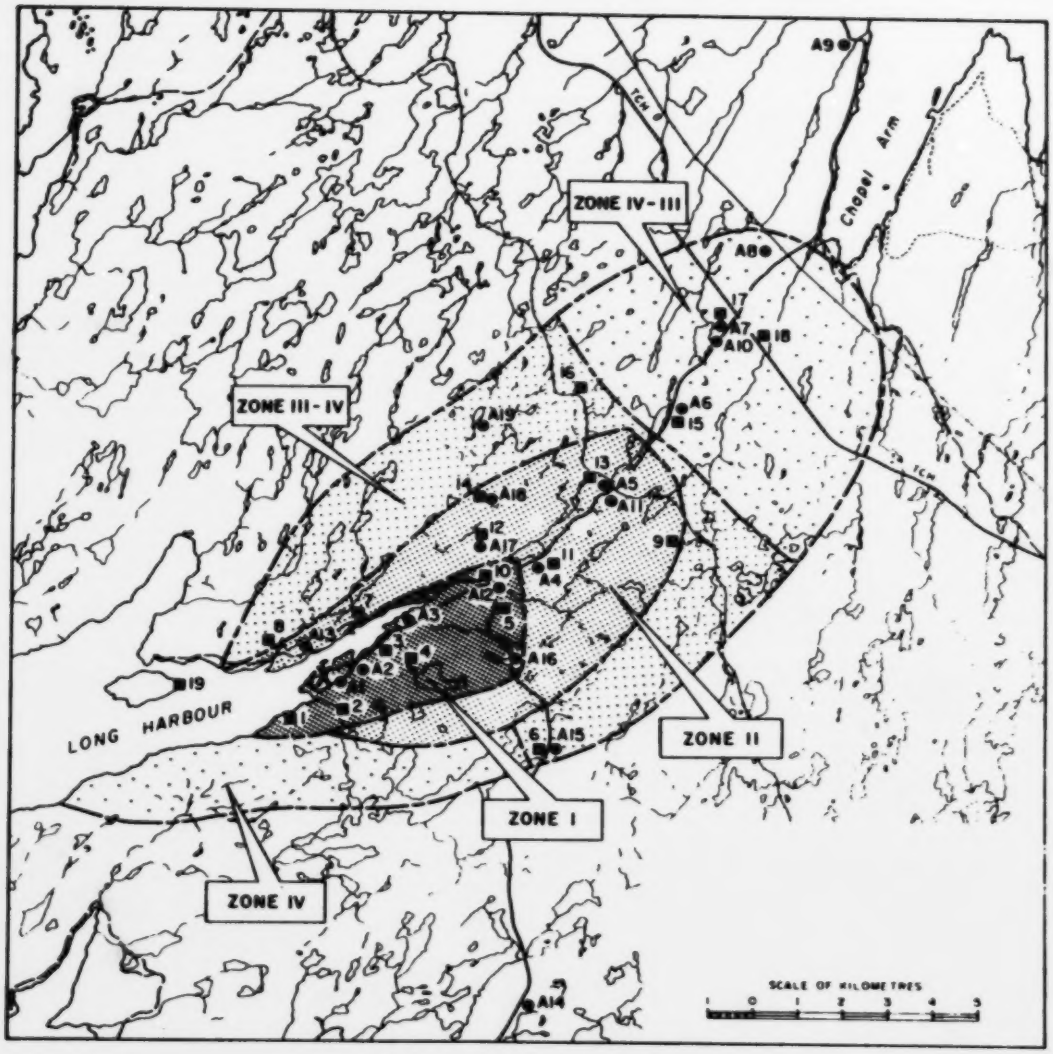

Fig. 2. Map showing location of permanent air (●) and vegetation (■) monitoring stations. (X) is the source of emission; Zones (I-IV) are the vegetation damage zones, Zone I being the most F-damaged and Zone IV, the least F-damaged.

The petri dishes were then hung from windward branches of balsam fir trees in duplicates at a minimum height of 2 m from ground level (Sidhu 1981). The petri dishes were located on the branches such that they were exposed to the oncoming wind from the emission source without obstruction from the neighbouring trees. The exposed filter papers were replaced and collected weekly.

In the laboratory the filter papers were soaked in 50 ml of Orion Total Strength Buffer (TISAB) in 100 ml plastic beakers for twelve hours and fluoride concentrations were determined using an Orion fluoride specific ion-electrode and pH mv-meter (Ionalyzer Model 801, Orion Research Inc.). Standards and blanks were run for each batch of filter papers. When filter papers were not analyzed immediatelty after collection, they were stored in sealed petri dishes in a refrigerator at 4°C for the interim period. The analytical results obtained were in the form of μg F/63.63 cm^2/7 days and were later standardized to μg F/dm^2/7 days.

Sidhu (1979) established an equation, Y = 5.54X, for converting the μg F/dm^2/n days to μg F/m^3 for the Long Harbour area. For exposure time of 1 day, 7 days and 30 days, μg F/m^3 values can be estimated by multiplying μg F/dm^2/n days with factors 0.2308, 0.0328 and 0.0076 respectively.

2.3 Meteorological Information for Long Harbour

The climate of Long Harbour is essentially a cool maritime type and modified locally by the presence of the sea. Summer is

of relatively short duration as temperatures over 16°C last from only the latter part of June to the middle of August. The monthly means of daily minimums, maximums and mean temperatures are summarized in Table 2. Five year means (1976 to 1980) of sunshine hours[1], average number of days with precipitation and relative humidity for June, July, August and September are summarized below.

	5-Year Means			
			Relative humidity	
Month	No. days with precipitation	Sunshine hours	Max.	Min.
June	14.4	207.4	90.9	65.9
July	13.4	214.8	89.7	65.8
August	14.4	194.2	89.5	67.7
September	17.0	146.4	89.5	67.4

The average annual precipitation in the Long Harbour area from 1981 to 1983 was over 1000 mm/year (Table 3). The data for 1981 to 1983 are presented in Table 3. During the period 1976 to 1980, 1977 was the driest year with rainfall slightly less than 1000mm/year (Sidhu 1981). In other years the annual precipitation was over 1200 mm.

[1]Sunshine hours and R.H. values are for St. John's summarized from "Meteorological Observations in Canada", Environment Canada, 1976-1980. No such available data is available for Long Harbour.

Table 2. Temperature (°C) data for Long Harbour, Newfoundland.

Year	Temperature Mean (°C)	Month											
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1981	Max.	2.8	3.4	3.8	7.5	13.3	15.2	19.1	19.9	17.7	13.1	8.4	5.3
	Min.	-4.6	-4.8	-1.9	-0.2	4.5	7.2	10.8	12.2	10.0	5.8	2.1	-0.9
	Monthly	-0.9	-0.7	2.8	3.7	8.9	11.2	15.0	16.1	13.9	9.5	5.3	2.2
1982	Max.	1.0	-1.9	1.4	7.5	10.1	12.9	17.9	18.9	-	9.9	8.6	14.3
	Min.	-5.2	-9.2	-6.5	-0.8	3.3	4.1	9.1	10.7	-	2.9	1.0	-3.2
	Monthly	-2.1	-5.6	-2.6	3.4	6.7	8.5	13.5	14.8	-	6.4	4.8	+0.7
1983	Max.	2.3	0.8	4.5	10.0	12.2	15.3	20.3	18.2	16.0	11.5	7.2	-
	Min.	-5.5	-5.7	-3.6	1.9	3.1	6.0	13.2	11.5	9.5	4.8	1.0	-
	Monthly	-1.6	-2.5	0.4	5.9	7.7	10.7	16.7	14.9	12.7	8.2	4.1	-

Table 3. Precipitation data (cm) for Long Harbour, Newfoundland for the period 1981 to 1983.

Year	Month												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1981	202.1	86.7	101.5	75.0	73.5	172.0	118.5	113.9	164.5	290.8	158.3	112.0	1168.8
1982	155.4	55.3	78.4	75.0	97.7	151.5	66.0	139.7	-	75.7	126.7	130.8	1152.2 11 months
1983	131.1	71.6	126.9	71.2	58.8	164.5	110.6	120.7	119.7	139.9	147.3	-	1262.3 11 months

The prevailing winds at Long Harbour over the growing period were from south to southwest at least 60% of the time at an average speed of 15 km h^{-1} (Sidhu 1981). The frequencies and mean wind speeds for 1981 to 1983 are summarized in Appendices A-1 to A-3. Because of the south and southwest prevailing wind during the growth period, most fluoride damage to vegetation had occurred in the northeast direction from the emission source (Sidhu and Roberts 1975).

3. RESULTS AND DISCUSSION

3.1 Levels of Fluoride in Air and Air Pollution Control Regulations

The results of 1980 to 1983 air monitoring using Na-formate plates are summarized in Tables 4 to 6. The values in the tables are in the form of μg $F/dm^2/7$ days and μg F/m^3. The latter were calculated from the former using the equation $Y = 5.54X$ (Sidhu 1979). The F-deposition on unexposed plates ranged from 1.09 to 4.49 μg $F/dm^2/7$ days. The values in Tables 4 to 6 are corrected for blanks.

The F-deposition, μg $F/dm^2/7$ days, fluctuated widely from week to week. For example, on Site A1 in 1983 (Table 6) the weekly F-deposition on fluoridation plates varied from 29.62 to 422.79 μg $F/dm^2/7$ days. Similar variations occurred in other years at each site (Table 4 to 6).

The average concentration of fluorides in air increased in 1981 and 1982 after a significant drop in 1979 and 1980. In 1983 there was a 13 to 70% drop in air concentration over the 1982 levels (Table 7). This drop in average concentration in 1983 was mostly due to lower concentrations in August as compared to the 1982 levels.

Table 4. Concentrations of gaseous fluorides in air at various locations form the source from 5 June to 8 September 1981

Monitoring Period	Site, Direction - Distance (km)											
	A_2, NE-1.4		A_4, N/-5.8		A_5, NE-8.0		A_6, NE-10.3		A_9, N/-18.7		A_{14}, SE-8.5	
	µgF/m³	µg F/dm²/ 7days	µgF/m³	µg F/dm²/ 7 days	µgF/m³	µg F/dm²/ 7 days	µgF/m³	µg F/dm²/ 7 days	µgF/m³	µg F/dm²/ 7 days	µgF/m³	µg F/dm²/ 7 days
5 June - 12 June	6.48	196.47	1.28	38.81	0.76	23.04	0.36	10.92	0.02	0.61	0.00	0.00
12 June - 19 June	8.04	243.77	0.94	28.50	0.22	6.67	0.09	2.73	0.02	0.61	0.02	0.61
19 June - 26 June	11.23	340.49	1.94	58.82	0.91	27.59	0.82	24.86	0.07	2.12	0.02	0.61
26 June - 3 July	3.74	113.40	1.57	46.70	0.53	16.07	0.24	7.28	0.02	0.61	0.02	0.61
3 July - 10 July	2.40	72.77	0.62	18.80	0.40	12.13	0.17	5.15	0.01	0.30	0.02	0.61
10 July - 17 July	2.15	65.19	0.47	14.25	0.66	20.01	0.46	13.95	0.03	0.91	0.01	0.30
17 July - 24 July	9.07	275.00	1.53	46.39	0.70	21.22	0.24	7.28	0.02	0.61	0.01	0.30
24 July - 31 July	8.64	261.96	1.71	51.85	0.73	22.13	0.24	7.28	0.01	0.30	0.06	1.82
31 July - 10 Aug.	9.22	279.54	1.69	51.24	0.83	25.16	0.42	12.73	0.01	0.30	0.03	0.91
10 Aug. - 17 Aug.	5.24	158.87	1.24	37.60	0.87	26.38	0.57	17.28	0.02	0.61	0.01	0.30
17 Aug. - 24 Aug.	3.78	114.61	1.19	36.08	0.76	23.04	0.49	14.86	0.04	1.21	0.06	1.82
24 Aug. - 31 Aug.	6.69	202.84	1.48	44.87	0.52	15.77	0.25	7.58	0.07	2.12	0.03	0.91
31 Aug. - 9 Sept.	2.03	61.55	0.63	19.10	0.13	3.94	0.06	1.82	0.00	0.00	0.03	0.91
Average for the period 5 June 81 - 8 Sept. 81	6.05	183.57	1.25	37.92	0.62	18.70	0.34	10.29	0.03	0.79	0.02	0.75

Table 5. Concentration of gaseous fluorides in air at various locations from the source from 2 June to 2 September 1982.

	Site, Direction - Distance (km)															
	A_2, NE - 1.4		Td, NE - 4.6		A_4, NE - 5.8		A_5, NE - 8.0		RLY Cr. - NE - 8.0		A_6, NE - 10.3		A_9, NE - 18.7		A_{14}, SE - 8.5	
Monitoring period	µg F/dm²/ 7 days	µg F/m³	µg F/dm²/ 7 days	µg F/m³	µg F/dm²/ 7 days	µg F/m³	µg F/dm²/ 7 days	µg F/m³	µg F/dm²/ 7 days	µg F/m³	µg F/dm²/ 7 days	µg F/m³	µg F/dm²/ 7 days	µg F/m³	µg F/dm²/ 7 days	µg F
2 Jun - 9 Jun '82	694.3	22.8	-	-	101.3	3.32	93.4	3.06	-	-	25.4	0.83	2.3	0.07	3.8	0.1
9 Jun - 17 Jun '82	120.8	3.96	187.6	6.15	78.0	2.56	38.3	1.27	40.6	1.33	9.2	0.30	1.4	0.05	2.8	0.0
17 Jun - 23 Jun '82	163.8	5.37	57.0	1.87	42.8	1.40	16.8	0.55	14.6	0.48	3.2	0.11	0.4	0.01	1.0	0.0
23 Jun - 30 Jun '82	376.2	12.36	120.8	3.96	48.5	1.59	47.0	1.54	42.0	1.38	25.2	0.83	1.1	0.03	8.4	0.2
30 Jun - 7 Jul '82	580.2	19.03	344.4	11.29	165.6	5.36	124.3	4.07	163.6	5.37	66.2	2.17	4.9	0.16	2.2	0.0
7 Jul - 14 Jul '82	635.0	20.83	548.5	17.99	139.8	4.58	72.2	2.37	82.8	2.72	36.1	1.18	8.1	0.27	12.8	0.4
14 Jul - 21 Jul '82	301.6	9.89	183.7	6.02	83.9	2.75	107.0	3.51	109.0	3.57	50.1	1.64	4.7	0.16	3.0	0.1
21 Jul - 29 Jul '82	257.5	8.45	226.0	7.41	80.7	2.65	61.0	2.00	52.3	1.71	16.5	0.54	1.96	0.06	2.8	0.9
29 Jul - 4 Aug '82	312.4	10.25	104.2	3.42	43.7	1.43	50.3	1.65	20.9	0.69	33.6	1.10	1.96	0.06	1.96	0.0
4 Aug - 11 Aug '82	174.9	5.7	80.2	2.63	29.7	0.97	10.3	0.34	19.7	0.65	5.1	0.17	1.96	0.06	1.96	0.0
11 Aug - 18 Aug '82	296.7	9.7	171.0	5.61	70.3	2.31	68.8	2.23	92.4	3.03	48.4	1.59	1.96	0.06	1.96	0.0
18 Aug - 26 Aug '82	328.2	10.7	71.5	2.34	27.5	0.90	32.2	1.06	3.1	0.10	12.1	0.40	1.14	0.04	0.78	0.0
26 Aug - 2 Sep '82	274.3	9.0	51.1	1.68	21.2	0.69	12.5	0.41	9.4	0.31	6.6	0.22	0.78	0.03	0.78	0.0
Average 2 Jun - 2 Sep '82	347.4	11.38	178.8	5.86	71.6	2.34	56.5	1.85	54.2	1.77	26.0	0.85	2.51	0.08	3.40	0.1

Table 6. Concentration of gaseous fluorides in air at various locations from the source from 31 May to 31 August, 1983

	Site, Direction - Distance (km)													
	A_2, NE - 1.4		TD, NE - 4.6		A_4, NE - 5.8		A_5, NE - 8.0		A_6, NE - 10.3		A_9, NE - 18.7		A_{14}, SE - 8.5	
Monitoring Period	µg F/dm²/ 7 days	µgF/m³	µg F/dm²/ 7 days	µgF/m³	µg F/dm²/ 7 days	µgF/m³	µg F/dm²/ 7 days	µgF/dm³	µg F/dm²/ 7 days	µgF/m³	µg F/dm²/ 7 days	µgF/m³	µg F/dm²/ 7 days	µgF/m³
31 May - 7 June	97.85	3.23	85.41	2.82	36.27	1.20	9.52	0.31	7.64	0.25	2.12	0.07	0.30	0.01
7 June - 14 June	299.62	9.88	129.03	4.25	79.62	2.63	65.67	2.16	23.31	0.77	0.77	0.02	1.02	0.03
14 June - 21 June	414.73	13.68	181.58	5.99	100.02	3.30	50.59	1.67	15.02	0.50	0.10	.01	0.58	0.02
21 June - 28 June	326.10	10.75	257.22	8.48	84.44	2.78	38.46	1.27	19.46	0.64	2.94	0.10	2.02	0.07
28 June - 5 July	304.05	10.03	176.43	5.82	70.49	2.32	75.39	2.49	32.29	1.06	1.25	0.04	0.74	0.02
5 July - 12 July	422.79	13.94	274.32	9.04	131.43	4.33	52.91	1.74	13.69	0.45	1.60	0.05	0.78	0.02
12 July - 19 July	157.76	5.20	129.57	4.27	39.14	1.29	21.50	0.71	10.68	0.35	1.18	0.04	0.20	0.01
19 July - 28 July	294.20	9.70	103.45	3.41	22.70	0.75	6.78	0.22	3.88	0.13	1.20	0.04	0.14	0.01
28 July - 2 Aug.	269.82	8.90	126.05	4.16	27.26	0.90	39.70	1.31	28.75	0.95	3.64	0.12	2.07	0.07
2 Aug. - 9 Aug.	106.60	3.52	126.13	4.16	33.44	1.10	38.46	1.27	-	-	8.47	0.28	0.78	.02
9 Aug. - 16 Aug.	155.26	5.12	104.67	3.45	34.95	1.15	25.03	0.82	10.41	0.34	0.94	0.03	2.65	0.09
16 Aug. - 23 Aug.	48.25	1.59	60.54	1.99	20.38	0.67	38.42	1.26	18.33	0.60	0.96	0.03	1.02	0.03
23 Aug. - 31 Aug.	29.62	0.98	22.70	0.75	5.72	0.19	13.81	0.46	18.53	0.61	3.23	0.11	0.83	0.03
Average for Period 31 May - 31 Aug. '83	225.13	7.42	136.70	4.51	52.76	1.74	36.63	1.21	16.83	0.55	2.18	0.07	1.01	0.03

Table 7. Percent change in F- concentration in air during 1976 to 1983 at different sites, Long Harbour, Newfoundland

Period of Comparison for Change*	Sites					
	A_2	A_4	A_5	A_6	A_9	A_{14}
From 1976 to 1977	-11	-10	+5	+17	-47	-
From 1977 to 1978	+51	-20	-18	-5	-13	+175
From 1978 to 1979	-29	-36	-25	-14	-43	-45
From 1979 to 1980	-55	-58	-47	-52	-50	0
From 1980 to 1981	+146	+137	+53	+41	+20	-59
From 1981 to 1982	+88	+89	+201	+153	+218	+86
From 1982 to 1983	-35	-26	-35	-70	-13	-70

* Percent Change = (Conc. current year - Conc. previous year) 100/conc. previous year. Value prior to year 1981 are from Sidhu (1981).

However, higher concentrations in 1983 foliage of balsam fir and alder may have been due to continuously higher F- concentrations in air during June and July of 1983 as compared to the same period in 1982. This aspect is further examined in section 3.2.

During 1981 to 1983 fluoride concentrations in air were inversely related to the NE-distance of the monitoring stations from the emission source (Tables 4 to 6) as in other years. The monitored levels of the fluoride in air were evaluated in terms of the acceptable air quality criteria set for Newfoundland (Government of Newfoundland and Labrador 1981 and 1982). These regulations were originally promulgated in 1981 and amended in 1982. The importance of the Newfoundland regulations is that both the fluoride levels in air and vegetation are considered together. Pertinent sections of the regulations[2] are summarized below:

[2] For details see Government of Newfoundland (1981 and 1982).

Column 1	Column 2	Column 3	Column 4	Column 5
Name of Contaminant	Units of Measurement	Average Contaminant or Total Amount of Contaminant	Appropriate Equivalents of Column 3 Where Appropriate (as Standard Conditions)	Period of Time
Fluoride (as hydrogen fluoride)	Micrograms of fluoride per cubic metre of air	0.45	0.5 ppb	30 days*
Total fluorides (gaseous & particulate)	Micrograms of fluoride per cubic metre of air	0.90	1.0 ppb	30 days*

* 30 day rolling average.

Fluoride Vegetation Standards

(i) Forage: Running averages of monthly samples collected through the growing season (May to November inclusive) of forage or hay or silage grown in the area as feed must not exceed 35 micrograms of fluoride per gram dry tissue in unwashed samples.

(ii) Deciduous trees: Fully expanded functional leaves of alder trees (Alnus crispa or Alnus rugosa) sampled in September of each year, must not exceed 130 micrograms fluoride per gram dry tissue in washed samples.

(iii) Conifers: Bud or needles from balsam fir (Abies balsamea) must not exceed 45 micrograms fluoride per gram dry tissue in washed samples for the current growth season and must not exceed 75 micrograms fluoride per gram dry tissue in washed samples for the previous growth season. Sampling is to take place during May and September of each year.

(iv) Grasses and Sedges: Grasses and sedges not subject to browsing, grazing or harvest for use in feeds or food must not exceed 60 micrograms fluoride per gram dry tissue in washed samples.

The Newfoundland Regulations 279/82 and Newfoundland Legislations 26/81 should be referred to for further details (Government of Newfoundland 1981, 1982). The fluoridation data for 1981 and 1983 indicate that fluoride levels in air were higher than the standards up to a NE-distance of 8 km in 1981 and 10.3 km in 1982 and 1983. The concentrations of fluoride in fall samples of vegetation supports this in Section 3.2.

3.2 Levels of Fluoride in Foliage

The accumulation levels of fluoride in foliage were proportional to the F- concentration in air during the monitoring period of 1981 to 1983, however, the levels were distinctly different in deciduous and coniferous species. The point is well illustrated by two species, alder and balsam fir, in Table 8. The F- accumulation in alder occurred at much faster (3-5 times) rate at all fluoride impacted sites. The rates of accumulation at control sites in the two species were similar (Table 9).

3.3 Fluoride Concentration in Air and Vegetation and Air Quality Standards

The examination of the air monitoring data showed that the F- concentration in the air increased by 20 to 146% in 1981 over the 1980 levels. There was a further increase of up to 88% in F- concentration in air in 1982. The fluoride levels in 1983 decreased over the 1982

Table 8. Average F- concentration (ppm, dry wt. basis) in foliage of four species collected at the end of growing period of each year from 1976 to 1983.

Year of Sampling	Species/ Growth Year	Sites - Direction and Distance (km) from Source					
		A_2, NE - 1.4	A_4, NE - 5.8	A_5, NE - 8.0	A_6, NE - 10.3	A_9, NE - 18.7	A_{14}, SE - 8.5
1976	Balsam fir						
	Current year	265	56	44	26	8	-
	Previous year	304	88	63	30	9	-
	Alder	1347	378	109	63	11	-
1977	Balsam fir						
	Current year	278	90	86	24	5	7
	Previous year	412	178	103	42	6	7
	Alder	1053	319	251	101	13	12
1978	Balsam fir						
	Current year	284	54	23	15	5	5
	Previous year	541	144	51	27	7	6
	Alder	808	173	110	51	11	9
1979	Balsam fir						
	Current year	249	62	28	32	7	12
	Previous year	454	153	55	51	8	18
	Alder	924	219	117	68	8	22
1980	Balsam fir						
	Current year	84	34	17	9	<5	6
	Previous year	223	70	30	20	5	7
	Alder	282	119	91	31	6	<5
1981	Balsam fir						
	Current year	108	34	20	13	<5	<5
	Previous year	248	50	40	17	5	<5
	Alder	282	106	93	24	6	<5
1982	Balsam fir						
	Current year	203	53	41	17	7	11
	Previous year	358	152	69	20	7	13
	Alder	1054	157	134	53	<5	<5
1983	Balsam fir						
	Current year	344	60	54	15	7	<5
	Previous year	606	149	100	32	8	5
	Alder	557	206	289	85	<5	<5

Table 9. NE-distance (km) from the emission source at which the provincial fluoride vegetation and air standards may not have been met:

	Year		
	1981	1982	1983
Air Quality Standard			
I. 30 day-average F- concentration 0.45 $\mu gHF/m^3$ (Compared values of gaseous fluorides are estimated from fluoridation plate data from Tables 4-6)	<8.0	<8.0	<10.3
II. Vegetation standard			
1. Alder foliage (130 ppm)	<5.8	<8.0	< 8.0
2. Balsam fir foliage: current year (45 ppm)	<5.8	<5.8	< 8.0
3. Previous year (75 ppm)	<5.8	<8.0	< 8.0

levels (Table 7). The F- concentration in foliage correlated well with the F- levels in air except that the levels of F- concentration in balsam fir were higher and in alder lower than the expected at site A_2. The higher levels in balsam fir at site A_2 may have been due to particulate deposits on the foliage because of its closer proximity to the source. Lower levels in alder were possibly due to the loss of severely affected foliage before the sampling period.

Ideally both "washed" and "unwashed" samples of foliage should be analysed to compare the data to the levels set for air quality standards and total amounts of fluoride being added to the forest system. Only unwashed samples were analysed in the present study:

(i) Washing of foliage occurs often (every alternate day) by rain under natural conditions.

(ii) Wildlife consumes "unwashed" samples.

(iii) Deposition of fluoride through leaf litter occurs as a result of defoliation of "unwashed" foliage.

(iv) Washing was excluded to decrease the number of samples which could be analysed by resources available.

(v) Industry and Provincial DOE analysed a limited number of washed samples.

A comparison of the F- concentration in air (fluoridation plates data) and F- accumulation levels in foliage to the Newfoundland air quality regulations for fluoride (Government of Newfoundland and Labrador 1981 and 1982) observed that the standards may not have been met up to a distance of 5.8 to 8.0 km in the NE direction from the emission source as shown in Table 9.

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Appendix A-1: Percent wind frequency (a, %) and average wind speed (b, km/h) from various directions, Long Harbour Newfoundland - 1981[Ψ]

Month	Speed (S) Frequency (F)	N	NE	E	SE	S	SW	W	NW	Calm
January*	S	10.3[a]	19.2	15.4	25.1	18.2	32.2	30.0	19.7	
	F	2[b]	13	4	3	5	29	20	21	3
February	S	4.0	13.6	6.0	12.6	11.2	22.5	24.8	11.7	
	F	1	19	8	6	7	18	29	10	2
March*	S	14.5	29.3	14.5	26.5	21.2	15.1	24.3	20.1	
	F	6	39	3	5	5	15	10	13	4
April*	S	22.1	24.6	12.3	19.4	13.3	24.8	26.9	23.8	
	F	2	9	6	2	5	56	8	11	1
May*	S	12.0	19.5	15.5	6.6	10.9	16.5	16.7	17.4	
	F	+	13	6	1	5	55	9	5	6
June	S		12.9	7.9	10.7	10.2	21.2	17.3	9.4	
	F		12	7	9	7	26	33	4	2
July	S	8.9	13.1	8.5	10.5	12.2	19.6	18.8	12.2	
	F	1	12	6	12	9	32	26	2	1
August	S	8.0	14.5	6.0	8.4	10.0	20.3	19.0	9.2	
	F	+	17	4	5	9	30	28	6	1
September	S	14.8	17.8	10.4	10.3	9.7	22.0	22.8	22.7	
	F	2	25	12	13	6	16	18	8	+
October	S	5.1	14.3	9.5	11.6	13.5	19.3	17.8	13.7	
	F	2	17	7	10	7	22	18	16	1
November	S	5.7	20.4	10.6	14.7	13.1	17.8	23.8	15.4	
	F	1	20	5	3	8	24	26	13	+
December*		Data Missing								

Ψ Summary prepared from climatological station reports and wind summary data from Atmospheric Environmental Services, Environment Canada - 1981.

+ Less than 0.5% but not zero.

* Arnold's Cove.

Appendix A-2: Percent wind frequency (a, %) and average wind speed (b, km/h) from various directions, long Harbour, Newfoundland - 1982[Ψ]

Month	Speed (S) Frequency (F)	N	NE	E	SE	S	SW	W	NW	Calm
January	S	4.4[a]	12.9	12.6	15.0	12.5	27.8	41.4	11.8	-
	F	4[b]	17	20	9	7	7	20	16	0
February*	S	28.6	28.1	28.6	36.1	13.0	21.2	25.3	37.6	-
	F	8	10	5	3	3	15	7	49	0
March	S	0	14.7	4.9	13.4	10.8	29.0	26.8	12.1	-
	F		13	2	12	3	29	29	11	1
April*	S	18.5	30.3	11.8	29.5	15.8	21.7	21.2	28.7	-
	F	4	1	1	2	12	47	18	14	1
May	S	3.0	18.7	8.2	9.5	9.0	21.1	15.2	13.2	-
	F	+	37	4	6	4	23	22	4	+
June	S	M	M	M	M	M	M	M	M	M
	F									
July	S	0	14.1	5.4	11.7	10.3	21.8	15.2	9.4	-
	F		6	2	10	6	49	23	3	1
August	S	2.0	8.6	6.9	8.2	10.9	20.8	19.4	6.0	-
	F	+	6	3	6	12	53	19	1	+
September	S	-	M	1	S	S	1	N	G	-
	F									
October	S	5.0	18.7	5.9	12.2	10.5	26.6	17.8	12.1	-
	F	1+	20	3	25	2	34	16	21	0
November	S	2.5	12.4	5.2	12.7	11.9	26.8	26.6	14.5	-
	F	4	14	3	6	1	44	17	13	1
December	S	14.7	18.0	10.4	11.7	18.8	23.2	25.6	12.1	-
	F	1	21	3	3	11	25	24	12	+

Ψ Summary prepared from climatological station reports and wind summary data from Atmospheric Environmental Services, Environment Canada - 1982.

+ Less than 0.5% but not zero.

* Arnold's Cove.

Appendix A-3: Percent wind frequency (a, %) and average wind speed (b, km/h) from various directions, Long Harbour, Newfoundland - 1983Ψ

Month	Speed (S) Frequency (F)	N	NE	E	SE	S	SW	W	NW	Calm
January	S	12.8[a]	17.3	12.8	15.3	16.0	26.8	26.6	12.4	-
	F	1[b]	21	1	7	6	29	17	18	+
February	S	-	15.5	2.5	11.2	+	17.9	19.6	12.3	-
	F	-	47	+	8	3.3	15	6	22	2
March	S	-	15.4	6.0	12.1	9.1	17.8	15.5	13.8	-
	F	-	23	3	24	1	23	7	18	1
April	S	-	19.6	6.2	13.0	11.5	15.8	12.7	7.5	-
	F	-	54	1	17	+	16	6	3	3
May	S	8.0	15.1	9.9	10.6	17.5	22.6	12.0	11.8	-
	F	+	39	2	11	1	29	11	5	2
June	S	-	11.0	5.1	11.4	8.9	20.4	11.3	9.6	-
	F	-	19	1	11	2	51	12	1	3
July	S	-	11.9	2.8	10.4	9.7	24.9	16.9	13.0	-
	F	-	14	1	21	1	49	12	1	1
August	S	-	14.5	7.5	10.5	11.5	22.0	17.3	14.3	-
	F	-	22	2	11	3	51	7	3	1
September	S	3.0	10.9	3.3	8.7	17.6	19.3	17.0	10.4	-
	F	+	24	1	16	4	32	13	9	1
October	S	-	14.4	3.3	10.3	12.5	23.6	17.2	9.3	-
	F	-	25	1	11	1	42	6	13	1
November	S	-	M	1	S	S	1	N	G	-
	F	-								
December	S	15.8	10.7	6.6	14.4	11.8	28.2	32.3	20.8	-
	F	2	9	1	14	2	27	14	29	2

Ψ Summary prepared from climatological station reports and wind summary data from Atmospheric Environmental Services, Environment Canada - 1983.

+ Less than 0.5% but not zero.